$m_e=0.5MeV/c^2$, $m_p=1Gev/c^2$ $hc=1240eV\cdot nm$, $h=4.14\times10^{-15} eV\cdot s=6.63\times10^{-34}J\cdot s$

1. (8) Give two examples of photon interactions with an atom. Explain each example briefly.

2. (8) A) Explain why stimulated emission is not usually observed.

B) Why helium is used in He-Ne laser? Can you use neon only?

3. (3) The origin of magnetism in solid is:

A) Electron spins
B) Interaction between atoms
C) Net magnetic moment of the atoms
D) Pauli exclusion principle
E) External magnetic field

4. (3) The decay of any individual nucleus is viewed as:

A) Exponential
B) Continuous
C) Random
D) Linear
E) None of the above

5. (3) Textbooks claim that the energy of decay Q is expressed differently for different β decay. For β^- decay and electron capture, $Q/c^2=M_{Parent}-M_{Daughter}$, however, for β^+ decay, $Q/c^2=M_{Parent}-(M_{Daughter} + 2m_e)$. Which statement is true?

A) In β^- decay, atomic electrons are involved
B) In electron capture, atomic electrons are involved
C) In β^+ decay, a pair of electrons are created
D) We are talking about the mass of the nucleus here
E) The books are wrong

6. (6) A hydrogen atom is in the 3D state. A) What are the possible values of j? B) What are the possible values of the magnitude of the total angular momentum? C) What are the possible z components of the total angular momentum?

7. (12) Consider two inertial reference frames. When an observer in each frame measures the following quantities, will each measurements made by the two observers always yield the same results? Explain your reason for each answer.

A) The distance between two events
B) The value of the electron charge
C) The speed of light
D) The time interval between two events

8. (6) What are the two main differences between the classical and quantum theory of conduction in metals?

9. (6) To what voltage must we accelerate electrons (for example, in electron microscope) if we wish to resolve a protein of diameter 4nm?

10. (10) The decay between two excited states of the nucleus of ^{48}Ti emits gamma ray of 1.3117 MeV. The upper state has a lifetime of 1.4ps, the lower state 3.0 ps. A) What is the fractional uncertainty $\Delta E/E$ in the energy of the gamma ray? B) What is the percentage spread in wavelength of the gamma ray ($\Delta\lambda/\lambda$)?

11. (10) The ground state wave function of Hydrogen atom is $\psi_{100}=C_{100}e^{-r/a0}$. What is the radial probability distribution function P(r) for this state? Show that P(r) has its maximum value at r=a_0.

12.(10) Determine the mass of a free particle whose wave function is the plane wave

$$\psi(x, t) = Ae^{i(2.5\times10^{11} x - 2.1\times10^{13} t)}$$

where distance is in meters and time in seconds.

13. (15) Assume that a neutron decays into a proton plus an electron without a neutrino. A) Assume that the kinetic energy of the electron is 0.8 MeV and calculate the momentum p of the electron in MeV/c. B) From momentum conservation, calculate the kinetic energy of the proton. C) In this situation, the energy shared by the proton and electron is 0.8 MeV. Calculation in B) gives a correction to the assumption of the energy of the electron to be 0.8 MeV. What percentage of 0.8 MeV is this correction?